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OPERATIONAL ASPECTS OF V/STOL AIRCRAFT

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OPERATIONAL ASPECTS OF V/STOL AIRCRAFT

By John P. Reeder*

Thus far only test-bed V/STOL aircraft have been built in this country. We have gained no appreciable operational experience with this type of aircraft in field operations. It is this operational experience which may well be the needed catalyst for the real development of V/STOL aircraft in both direction and application.

The critical aspects of V/STOL operation occur in the terminal area. Four of the important aspects will be discussed in the following order:

(1) The Conversion Maneuver

(2) The Instrument Approach

(3) Control and Stabilization for Low-Speed Flight

(4) The Ground Erosion and Debris Problems

The Conversion Maneuver

The safety and rapidity of performing the conversion maneuver are strongly dependent on the simplicity of pilot controls and flexibility permitted in the operation of the conversion elements. The aircraft types in which only one conversion control has been necessary in addition to the basic aircraft systems have proved reasonably straightforward and simple to operate, provided the conversion control can be used independently of other configuration changes, trim systems, or engine power. In addition, the conversion elements should be continuously variable throughout their full range so that large and sudden changes in aircraft attitude are not required, and the aircraft can be flown at any desired speed by adjusting the conversion elements for proper balance of lift and drag forces.

In contrast, the use of more than one additional control or the necessary programing of several operations markedly increases the training time and promotes the possibility of pilot errors resulting in loss of control. In addition, the rate of conversion must necessarily be slowed.

The Instrument Approach

In preparation to land in restricted landing areas under weather or high density traffic conditions the V/STOL aircraft will be slowed to below airplane speeds, or partially converted, to maneuver into

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position for the final approach. The traffic control area to handle such aircraft can be reduced in dimensions in nearly direct proportion to the pattern speed.

Figure 1 compares a typical V/STOL pattern with a typical airplane pattern. The V/STOL is assumed to be landing in a 500-foot field and the airplane on a 5000-foot runway. Time is the governing factor in establishing the alinement and glide path legs to the landing. Experience indicates that 1 to 1-1/2 minutes are required to establish alinement and 1-1/2 minutes are required to establish the glide path. At present it is not considered feasible to follow a precision vertical or curved flight path to a landing by instruments, nor is it considered practical to change configuration and /or speed very greatly during the final approach. Thus it appears that about 4 minutes will be required at reduced speed in a partially converted configuration for an instrument approach.

The aircraft which must slow to zero speed for landing, or must land in the confines of a 500-foot field with 50-foot obstructions must decelerate to zero speed in the distance from which the landing spot is first sighted, as limited by atmospheric visibility or ceiling. For a conventional airplane, on the other hand, the vertical velocity only has to be arrested near the point first sighted and the major part of the speed can be lost on a lengthy runway. Figure 2 shows the distance in which an aircraft can be slowed to a stop from various speeds at an operationally feasible deceleration of 0.15g. This stopping distance represents the minimum visibility or slant visual range in which the stop can be made. This is converted into an operational angle-of-approach, as limited by a 500-fpm rate of descent, and the corresponding ceiling in figure 3. Thus, in a visibility of 1/8 mile the approach speed cannot exceed about 47 knots. At the 6° approach angle indicated the corresponding ceiling would be about 70 feet. The important idea to be gleaned from this is that V/STOL aircraft must be capable of sustained operation at lower-than-airplane speeds to accomplish an instrument approach to a limited sized landing field in low ceiling or visibility conditions.

Control and Stabilization for Low-Speed Flight

In order to achieve a landing distance of 500 feet over a 50-foot obstacle the approach speed of an STOL aircraft must be limited to about 40 knots. In addition to the lift capability to fly at speeds less than 70 knots, or so, the control about one or more axes must be augmented to some degree. The roll axis is important as the basic heading and lateral positioning control. Normal ailerons have proved inadequate for control at these low speeds. The Breguet 941 and Hawker P-1127 utilize augmented roll control power and have illustrated how relatively successful STOL operation can be as a result. Also, the demand for quick and precise heading control during a low-speed precision instrument approach and the need for removing drift and for controlling during an STOL landing touchdown places a demand for rather high control response about the yaw axis, which unaugmented systems don't have. Recent studies with a large tandem research helicopter of 15,000 pounds weight have shown that a yaw control response per inch of control displacement equal to that of the present military specifications for helicopters (MIL H-8501A) was necessary for good control during instrument approaches at a speed of 50 knots. This response was double that provided in the basic aircraft. The point to be made is that control powers for an STOL operating at 40 to 50 knots must be augmented over those possible with conventional surface controls at least for the roll and yaw axes.

With regard to the need for stability augmentation systems for low speed flight, it is possible to draw some pertinent conclusions now. The stability augmentation requirements are most severe at the lowest speed of flight possible where aerodynamic damping of the airframe is at a minimum. There is now ample evidence that hovering aircraft can have safe hovering characteristics for visual flight without the need for stability augmentation systems if proper attention is given to providing the necessary control power and desirable sensitivities about all axes. The Hawker P-1127 is a good example. This does not mean that it is not desirable to have stability augmentation for many tasks such as precision instrument approaches. On the contrary, stability augmentation is very desirable for the successful completion of such tasks. The point is, however, that relatively simple and cheap single-channel systems of limited authority can be employed with reversion to manual control adequate in case of a failure.

The Ground Erosion and Debris Problems

Experience with the effects of downward deflected slipstream on ground erosion and recirculation effects is accumulating slowly, but the effects on operational usage of the aircraft have yet to be learned. The jet types have the highest slipstream velocities immediately under the aircraft and will certainly stir up dust and debris. In addition, hot air ingestion by the engine occurs. However, with the jet concentrated at the center of the aircraft recirculation effects and obstruction to vision in hovering near the ground are minimized relative to some other types. The slipstream tends to spread without recirculation except in the direction from which the wind is blowing. The VTOL aircraft with laterally (or otherwise) disposed lifting systems will, within 10 to 20 feet of the ground, suffer more from visibility and debris pickup because the high velocity downwash fields are forced to meet and mix violently under the aircraft. The air in the region of mixing is forced upward and outward at right angles to the line connecting the centers of the lifting systems as shown in figure 4. Thus a region of severely restricted visibility is apt to lie ahead in about a 20° wedge about the plane of symmetry when headed into the wind. If vertical take-offs are made followed by an air run in close proximity to the ground where the dust or debris restricts visibility ahead it may be possible to accelerate along a take-off path inclined to the plane of symmetry in a slightly banked and yawed attitude in order to see along the track being followed until the debris is cleared. Landing vertically may be a more serious problem since the aircraft is in its final stages of deceleration when the debris is forced ahead of the aircraft. The technique of yawing to see along the track may be applicable here also. In the take-off or landing case, of course, forward speed can be employed to prevent the forward circulation.

In the case of the simple jet lift engine the hot exhaust will have to be deflected from direct ground impingement by some means for all but the take-off and landing as it burns grass, shatters concrete, blasts loose soil, and overheats tires and structure of the aircraft. Engines of the fan or bypass type have considerably lower exhaust temperatures and velocities, in the normal case. The vectored thrust engine exhaust is normally deflected aft except for the take-off and landing operation. In the case of the P-1127, grass has been burned for take-off but not necessarily during landing, although the grass will erode away with continued exposure. It has been found that sod surfaces are generally resistant to erosion effects at jet-type engine dynamic pressure of 1000-2000 pounds per square foot, dependent on the type of grass. In some cases the sod surface has been lifted from the ground even with a cold jet, probably due to a buildup in pressure beneath the sod surface. A recent experience with the X-14A at Ames is of considerable significance in this regard. The aircraft had been hovering at several heights over an area with wet sod of native rye grass. After 5 seconds hover at a wheel height of 2 feet (jet height of 6 feet) a large area of sod suddenly erupted under the aircraft, throwing pieces of sod 8 to 10 feet into the air. The aircraft was landed immediately and the engines shut down. The engines ingested considerable earth. A photograph of the crater is shown in figure 5. It was about 7 inches deep at the center. The soil that erupted was moist to a depth greater than that eroded and consisted of clay, primarily, with some sand and a few rocks. These experiences indicate that jet VTOL aircraft should operate from prepared or protected surfaces wherever possible.

CONCLUSIONS

1. The pilot should have only one additional control to operate for conversion. Also, the degree of conversion should be continuously variable through the complete range.

2. Instrument landing patterns can be reduced in size approximately in proportion to the speed, since time is the governing factor.

3. At least 4 minutes will be required at reduced speeds in a partially converted configuration to perform an instrument approach in low ceiling or visibility conditions.

4. The distance from which the landing spot can be seen, in the final analysis, determines the maximum speed on the approach for VTOL operation. This results in a speed of about 47 knots for 1/8-mile visibility, assuming 0.15g deceleration to zero speed in the air. This represents a ceiling of 70 feet on a 6° glide slope for a limiting rate of descent of 500 fpm.

5. Control power requirements for STOL aircraft operating at 40 to 50 knots are greater than can be obtained by conventional surface controls. Roll response is most important. Directional control response becomes important for the STOL landing and the V/STOL instrument low approach.

6. Stability augmentation is desirable, but need not be necessary for safe operation in case of failure of the augmentation.

7. Ground erosion and structural heating problems will be maximum and very serious for the aircraft having pure jet lift engines. Hot gas and debris ingestion, and dust restriction to visibility will be most serious with the types having laterally and/or longitudinally disposed lift elements. If vertical take-offs and landings are not possible, it may be necessary to take off and land at forward speeds to avoid these effects.

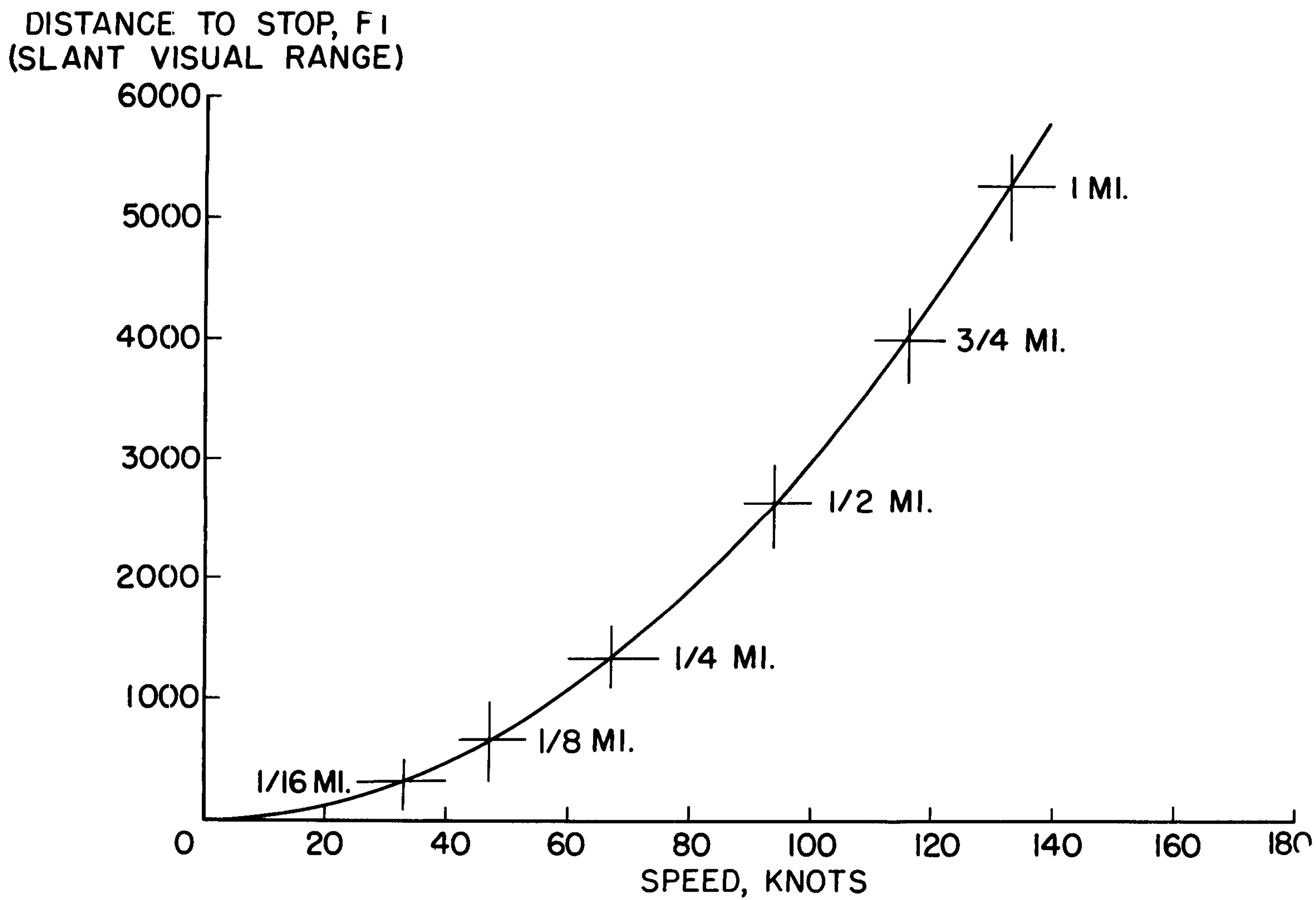

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Figure 2.- Distance required to stop in the air at 0.15g deceleration as a function of speed.

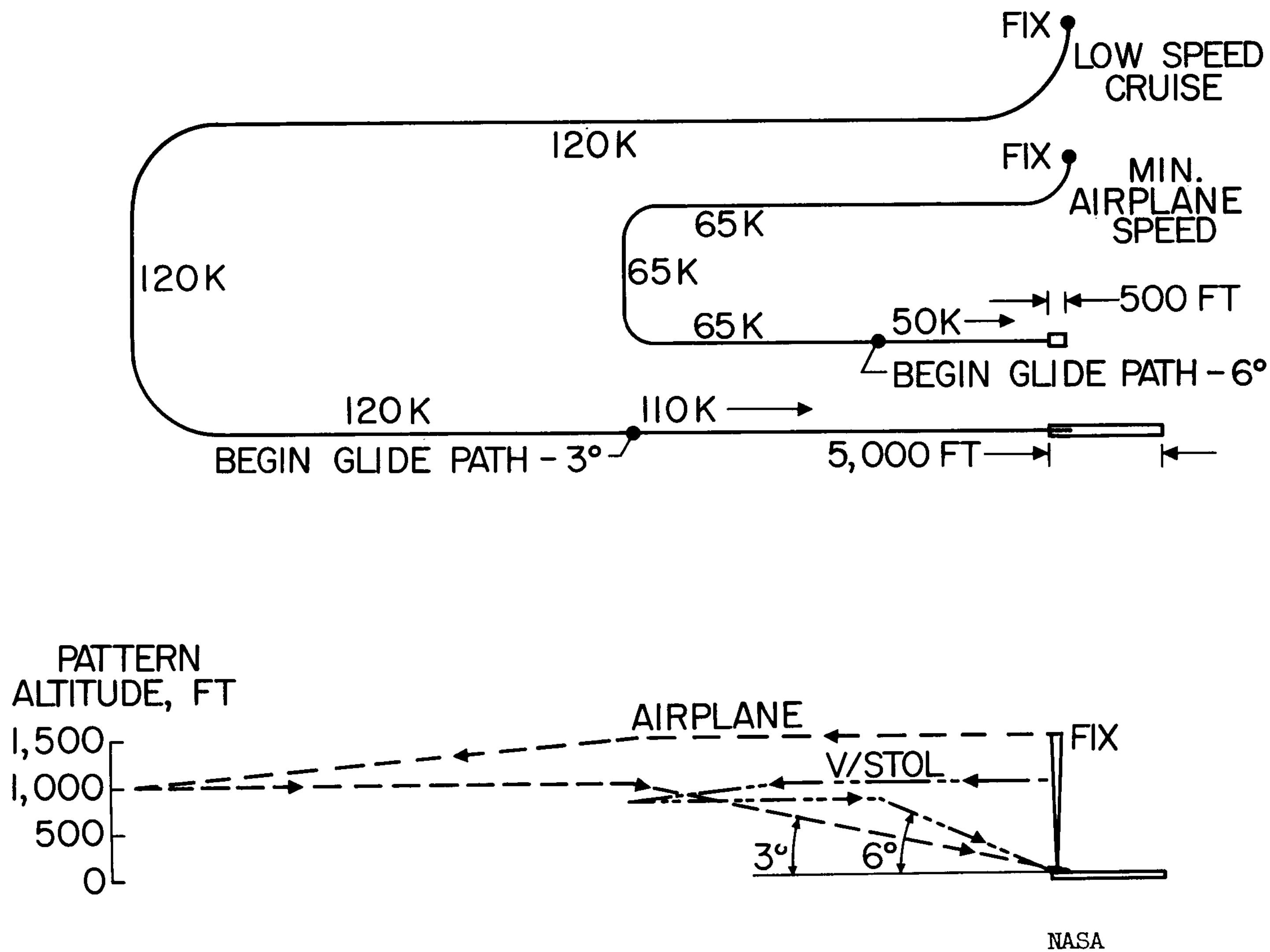

Figure 1.- A comparison of instrument approach patterns for V/STOL and conventional aircraft.

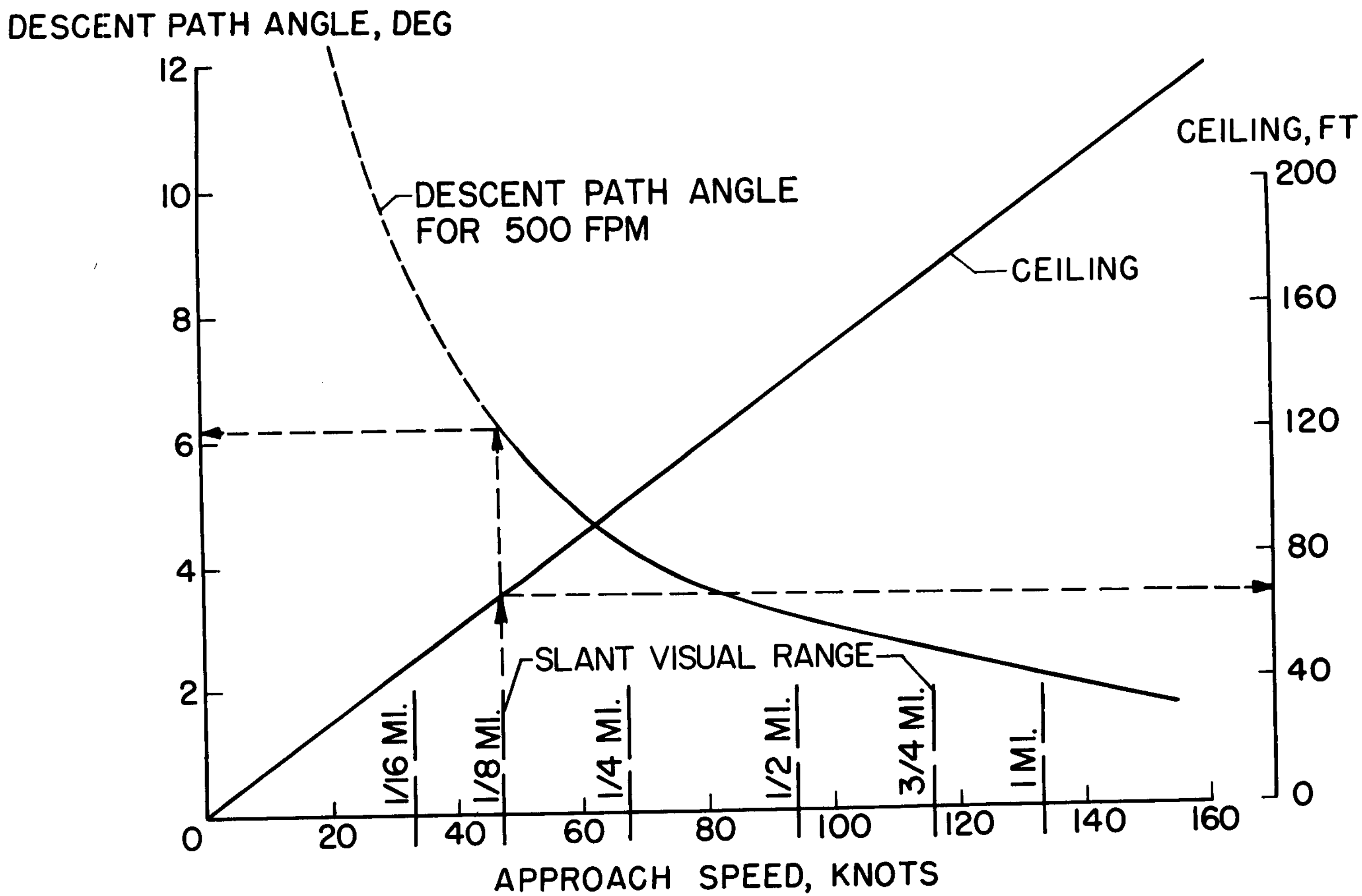

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Figure 3.- Descent angle at 500-fpm descent and corresponding ceiling limitations for zero speed landings, assuming 0.15g deceleration after breakout.

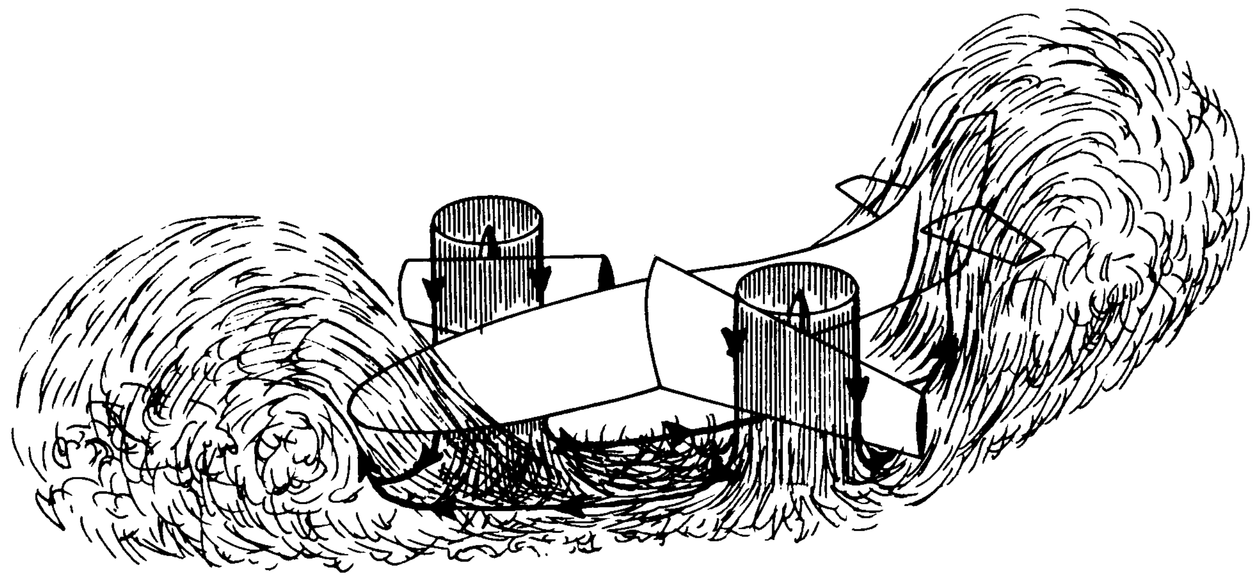

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Figure 4.- Slipstream interference pattern for a two-rotor VTOL aircraft.

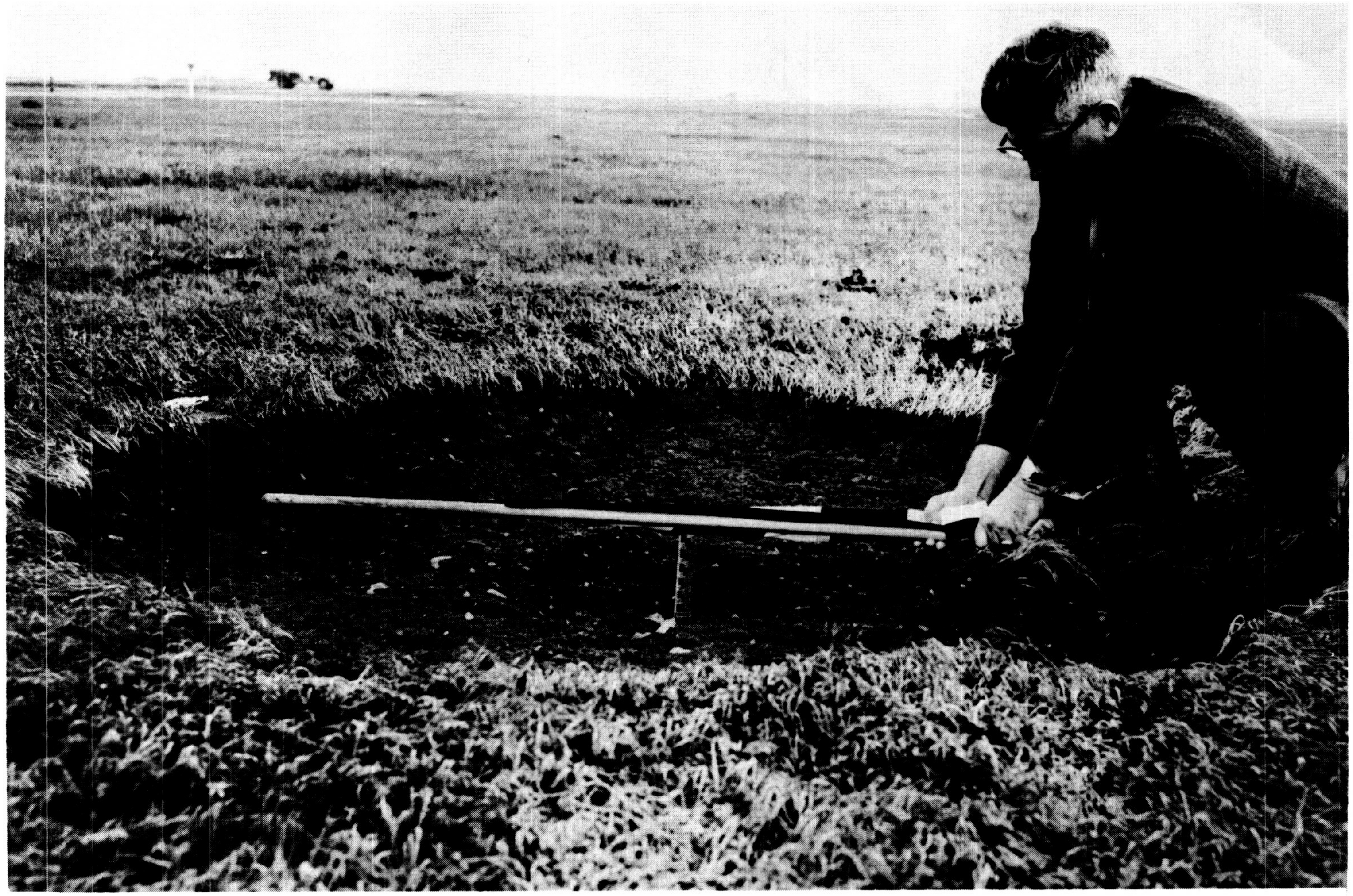

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Figure 5.- Crater caused by exhaust of X-14A while hovering over wet sod.

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